The Mu3e Experiment

Searching for the lepton flavour violating decay $\mu \to eee$

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The Mu3e experiment is a novel experiment to search for the lepton flavour violating (LFV) decay $\mu \to eee$ with an ultimate sensitivity of one in $10^{16}$ muon decays. This would be an improvement in sensitivity by four orders of magnitude compared to previous experiments. The Standard Model prediction for the branching ratio of this decay mode is less than one in $10^{50}$. Any observation of such a decay is therefore a clear indicator of new physics.

The improvements are made possible by a novel experimental design based on high voltage monolithic active pixel sensors for high spatial resolution and fast readout and hodoscopes using scintillating fibres and tiles providing precise timing information at high particle rates.

**Abstract**

**Requirements**
- High rates
- Excellent momentum resolution
- Great vertex resolution
- Good timing resolution
- Extremely low material budget

**Signal**
- $\sum \mathbf{p}_i = 0$

**Backgrounds**
- Combinatorial $\sum \mathbf{p}_i \neq 0$

**Detector Concept**

**Transverse View**
- Phase 2: Recurl station + Timing tiles
- Phase 1b: Recurl station + Timing tiles + Timing fibres
- Phase 1a: Central pixel detector + Timing tiles + Timing fibres

**Longitudinal View**
- Target: Inner pixel layers
- Outer pixel layers

**Muon Beam**
- Existing / Future Beamlines at the Paul-Scherrer Institute, Switzerland

**Pixel Sensors**
- High Voltage Monolithic Active Pixel Sensors
- $80 \times 80 \mu m^2$ pixel size
- Thinned to $< 50 \mu m$
- Total thickness of 4 layers $< 4 \times X_0$
- Binary readout
- Total number of pixels $\sim 300$ million

**Target**
- Extended hollow double cone target
- $\sim 70 \mu m$ Aluminium
- Reduces combinatorial background

**Timing**
- $200 \mu m$ scintillating fibres in the central detector
- Thick ($\sim 1 cm$) scintillating tiles in the recurl stations for precise timing

**Magnet & Cooling**
- Solenoid Magnet $\sim 1 T$
- Cooling using gaseous Helium

**Readout**
- Triggerless readout $\sim 100$ Gbyte / s
- Online tracking and event filter based on GPUs
- Data reduction to $\sim 50$ MByte / s for storage and offline analysis

**Expected Performance for Phase 2 (simulated)**

- Single Track Momentum Resolution
- Signal Decay Mass Resolution
- Branching Ratio Sensitivity

**Central Detector and Construction Tool**
- Sensor Strip Sandwich
- Thinned HV-MAPS Sensors
- $25 \mu m$ Flexprint Power & Signals
- $25 \mu m$ Kapton Support Structure

**Mechanical Prototypes**
- Kapton Support Structure
- Inner Pixel Layers
- Outer Pixel Layers (Single Segment)

**Setup at DESY**
- MuPix Prototype
- Electron beam 3-6 GeV

**Setup at CERN**
- MuPix Prototype v2
- High Voltage Monolithic Active Pixel Sensor
- $42 \times 36$ pixels
- $10 \times 89 \mu m^2$ pixel size
- Binary Readout
- Single Threshold
- Developed by Ivan Peric, ZITI Mannheim

**Example Measurement: Single Hit Resolution**
- Work in Progress

**Internal View**
- Not coincident

**Signal**
- $\sum \mathbf{p}_i = 0$

**Combinatorial**
- $\sum \mathbf{p}_i \neq 0$

**Particles**
- $\mu$, $\nu$, $e$, $\pi$, $K$, $\phi$, $\Delta$, $\Xi$